International canyons workshop

Abstracts

Talks

Global distribution of large submarine canyons: geomorphic differences between active and passive continental margins

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The aim of this study is to assess the global occurrence of large submarine canyons to provide context and guidance for discussions regarding canyon occurrence, distribution, geological and oceanographic significance and conservation. Based on an analysis of the ETOPO1 data set, this study has compiled the first inventory of 5,849 separate large submarine canyons in the world ocean. Active continental margins contain 15% more canyons (2,586, equal to 44.2% of all canyons) than passive margins (2,244, equal to 38.4%) and the canyons are steeper, shorter, more dendritic and more closely spaced on active than on passive continental margins. This study confirms observations of earlier workers that a relationship exists between canyon slope and canyon spacing (increased canyon slope correlates with closer canyon spacing). The greatest canyon spacing occurs in the Arctic and the Antarctic whereas canyons are more closely spaced in the Mediterranean than in other areas.

River-associated, shelf-incising canyons are more numerous on active continental margins (n = 119) than on passive margins (n = 34). They are most common on the western margins of South and North America where they comprise 11.7% and 8.6% of canyons respectively, but are absent from the margins of Australia and Antarctica. Geographic areas having relatively high rates of sediment export to continental margins, from either glacial or fluvial sources operating over geologic timescales, have greater numbers of shelf-incising canyons than geographic areas having relatively low rates of sediment export to continental margins. This observation is consistent with the origins of some canyons being related to erosive turbidity flows derived from fluvial and shelf sediment sources

Other workers have shown that benthic ecosystems in shelf-incising canyons contain greater diversity and biomass than non-incising canyons, and that ecosystems located above 1,500 m water depth are more vulnerable to destructive fishing practices (bottom trawling) and ocean acidification caused by anthropogenic climate change. The present study provides the means to assess the relative significance of canyons located in different geographic regions. On this basis, the importance of conservation for submarine canyon ecosystems is greater for Australia, islands and northeast Asia than for other regions.

Drainage network analysis of a submarine canyon: The Foix canyon (NW Mediterranean Sea)

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Submarine gullies are relatively small valleys that occur in a variety of submarine slopes. They are very common in continental slopes and in submarine canyon heads and flanks, where they often form tributary networks. The shelf-incising submarine Foix Canyon System (FCS) is located in the north-western Mediterranean Sea. Numerous, well-developed and morphologically diverse gullies carve its two heads and flanks. The objective of this study is to analyse the drainage network of the FCS and decipher the role of gullies in its evolution. Submarine gully and canyon networks were extracted from swath bathymetry data of 50 m grid size using a Geographic Information System (GIS). A systematic morphometric analysis was carried out on drainage network of the FCS by using the Horton-Strahler method. To detect relevant morphological changes along valley sections, the drainage density, the stream frequency and the drainage area relief parameters were applied. Furthermore, a branching index (Ib) was developed to characterise the geometry of the submarine drainage network. At a fine scale, we have identified two types of canyon flank gullies, namely ñrim gulliesò and ñtoe gulliesò: (1) rim gullies form large, dendritic networks that extend from the canyon thalweg up to the canyon rim, and (2) toe gullies form smaller pinnate networks restricted to the lower part of the canyon flanks. Rim gullies formation and development is interpreted as the main process responsible for canyon head growth and across-flank transport of material from the continental shelf. Toe gullies, on the other hand, are the morphological expression ofthe rejuvenation of rim gullies and the canyon itself. This study helps to identify a variety of gullies and the processes they result from and provides a morphometric methodology to characterise submarine drainage networks at fine resolution scales.

Morphologies and evolution of submarine canyons in the Gulf of Palermo (Southern Tyrrhenian Sea)

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Seven submarine canyons were mapped with Multi Beam echosounder and high resolution seismics in the Gulf of Palermo (Southern Tyrrhenian Sea). The canyons are confined to the upper slope or indent the shelf-edge and enter the Palermo intraslope basin at a depth of around 1300 m. The canyons evolved through concurrent top-down turbiditic processes and bottom-up retrogressive mass failures. Most of the mass failure features of the area are related to canyon shaping processes and only few of them are found not confined to the canyons. The geological elements that control the evolution of the canyons and induce sediment instability correspond to the steep slope gradient, especially in the western sector of the Gulf, and secondary to the structural features of the Palermo offshore, with direct faults and antiform structures coinciding with some of the canyon heads. Furthermore, the occurrence of pockmarks and highs that probably consist of authigenic carbonates above faulted and folded strata suggests a local relationship between structural control, fluid escape processes and mass failure. The presented high-resolution dataset is also a valuable base for forthcoming works

focussing on evaluate the geo-hazard potential related to slope failure in the Gulf of Palermo area.

Physical oceanography of the Nazaré Canyon (W Portugal) - present views and future perspectives

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During the last decade the Instituto Hidrográfico (IH) developed a continuous effort in the monitoring of the Nazare Canyon. This canyon is the largest of the many submarine canyons that cut the Portuguese continental margin, and one of the largest of the European margin. It extends from abyssal depths of 5000m depth to just a few hundreds of meters from shore, cutting all the continental shelf and slope and providing a connection between the nearshore and deep ocean environments.

The monitoring program started in late 2002, in the framework of the European project EUROSTRATAFORM (FP5), and continued until the present under projects HERMES (FP6) and HERMIONE (FP7, ongoing). It involved a permanent array of currentmeter moorings deployed along the canyons axis, at bottom depths of 3300m, 1700m and 700m (this one only after 2005), and instrumented from near surface to near bottom. The long-time mooring measurements were complemented by data collected during multidisciplinary surveys covering the complete area of influence of the canyon. These included CTD and current profiles and water samples for particle matter, nutrients, trace metals and phytoplankton evaluation.

Recently the monitoring capacities installed by IH in the Nazare Canyon area were largely improved trough the convergence of efforts developed in different projects. Project MONICAN (Monitoring of Nazare Canyon area) installed a real-time transmission system that includes two multi-parametric buoys deployed one in the middle canyon area (2200m depth) and the other at mid-shelf close to the canyon (90m depth). These buoys are presently providing real-time measurements of the conditions in the upper water column, but on-going developments aims to extend their capacities in order to allow the real-time transmission of data collected at the bottom. Project SIMOC installed an HF-radar system that provided surface currents in the global area of the upper canyon section. The system was operated in testing mode during a 6 month period in 2011 and is now planned to be permanently installed in the Nazare Canyon area in 2012.

In this presentation I summarize some of the main aspects of the physical oceanography of the Nazare Canyon that emerged from the analysis of the data collected by IH monitoring program, and also from numerical simulations conducted recently. I also discuss a few aspects related with the monitoring activity (and inherent difficulties) in such a hostile environment and give a global perspective of the future development of the monitoring activity conducted by IH in the Nazare Canyon.

Internal tide energetics in Monterey Submarine Canyon

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The M2 internal tide in Monterey Submarine Canyon is simulated using a modified version of the Princeton Ocean Model. Most of the internal tide energy entering the canyon is generated to the south, on Sur Slope and at the head of Carmel Canyon. The internal tide is topographically steered around the large canyon meanders. Depth-integrated baroclinic energy fluxes are up-canyon and largest near the canyon axis. Maximum energy densities and fluxes occur around Monterey and San Gregorio Meanders. The up-canyon energy flux is bottom-intensified, suggesting topographic focusing occurs. Net along-canyon energy flux decreases almost monotonically from 9 MW at the canyon mouth to 1 MW at Gooseneck Meander, implying high levels of internal tide dissipation occur. The depth-integrated energy flux across the 200-m isobath is small along the majority of the canyon rim but increases by over an order of magnitude near the canyon head where internal tide energy escapes onto the shelf. Reducing the size of the model domain to exclude remote areas of high barotropic-to-baroclinic energy conversion decreases the depth-integrated energy flux in the upper canyon by 20%. However, quantifying the role of remote internal tide generation sites is complicated by a pressure perturbation feedback between baroclinic energy flux and barotropic-to-baroclinic energy conversion.

Suspended sediment transport in the Cap de Creus Submarine Canyon by cascading and storms

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Significant sediment transport events to the northwestern Mediterranean basin occur annually during wintertime through the Cap de Creus Submarine Canyon. These events can be caused by severe winter Eï SE storms with or without being associated with a dense shelf-water cascading (DSWC) event or by exceptionally intense and persistent DSWC episodes alone. Shelf sediment resuspended by major E-SE storms is more efficiently transported downcanyon when the subsequent storm-induced downwelling occurs together with a DSWC event. Under these conditions, the exported shelf sediment is usually transported to the upper canyon area, where it accumulates temporally. Occasionally, when less frequent and storm-unrelated deep DSWC pulses occur, they resuspend and transport further downslope the sediment from these temporary upper canyon deposits. When erodible sediment of the shelf and the canyon head is exhausted, deep cascading can generate sediment transport increases only from resuspension of these mid-canyon temporary deposits.

Beyond the mid canyon, part of the deep dense water plume along with its sedimentary load can leave the canyon confinement and be transported along the southern open mid-slope, whereas some dense water pulses still progress downcanyon towards the continental rise and basin. This is in accordance with the presence of furrows in the CCC down to about 1400 m depth where the canyon section widens and the height of the southern flank drops. These topographic factors added to the reduction of the density excess of the dense water plume may produce a deceleration of the bottom flow, losing part of its erosive capability and coarse sediment load and leaving the canyon confinement. A clear multi-step sediment transport mechanism occurs in this submarine canyon: involving storms and regular DSWC events from the shelf to the upper canyon sector and deep DSWC pulses from the upper canyon to the lower parts of the continental margin.

Temporal and spatial variability of POC fluxes through the W and SW Cretan Margin Canyons systems to the deep NE Mediterranean Basin

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The W Cretan Straits are incised by two main canyons which have a common foot at a basin of ~3000m, while the SW Cretan margin is characterized by the appearance of the Samaria submarine Canyon.

To define the amount of material exported through the canyon systems down to the deep Ionian Sea and the role the local canyons in the transferring of particulate matter and specifically of organic carbon, six sediment trap arrays were deployed along the canyons and at the deep Ionian basin, in the framework of HERMES (SW Cretan margin, 1/June/2005 ï 15/May/2006) and HERMIONE (W Cretan Straits, 4/June/2010 ï 15/May/2011) projects.

Along the Samaria submarine canyon, total mass flux decreased downwards (352, 79 and 59 mg m ‑ 2 d ‑ 1) and consequently the organic C flux followed the same trend (4.8, 2.1 and 1.5 mg m ‑ 2 d ‑ 1). In the W Cretan Straits, the eastern canyon was more active, transferring more particulate matter (151 mg m ‑ 2 d ‑ 1), than the western canyon (106 mg m ‑ 2 d ‑ 1), down to 3000m depth of Ionian Sea. The total mass flux at the deep Ionian basin was 128 mg m ‑ 2 d ‑ 1. The organic C fluxes (covered only the first deployment), were 4.5 mg m ‑ 2 d ‑ 1 in the eastern, 3.2 mg m ‑ 2 d ‑ 1 in the western canyon and 3 mg m ‑ 2 d ‑ 1 at the Ionian basin.

The Var canyon: influence of sediment gravity flows on macrobenthic communities

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In the framework of the project ENVAR (HERMES-WP5-canyon), the macrofaunal communities were investigated together with selected environmental parameters at three sites along the Var submarine system from September 2005 to October 2007 as part of the study of the influence of the Var canyon activities on the benthic ecosystem. One site is located in the

upper part of the canyon (1780m) and two sites are located seaward in the channel part, one in the channel thalweg (2150m) and the other one at the same level on the levee (1900m).

Macrofaunal communities at the three sites differed in terms of densities, taxonomic composition and vertical distribution in the sediment column but not in terms of diversity at the identification level used (phylum to family). The most significant variations were found between the upper site and the two lower sites in relation with contrasted hydrodynamic and particulate input regimes in both areas. The upper site is under the influence of river floods, its environment is dynamic, subject to short episodes of high sedimentation as well as erosion while the lower sites experience more stable environmental conditions, largely influenced by regional environmental settings, particularly by the Liguro-Provençal current that also shows inter-seasonal and inter-annual variations in current velocities. These contrasted and unstable environmental conditions drove changes in the community composition and distribution along the study period both at the upper site and at the lower levee site, for which biological data sets were available from four cruises.

Impact of bottom trawling on sediment resuspension and transport in the Palamós (La Fonera) submarine canyon

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We present a compilation of novel results and past studies carried out in the La Fonera (or Palamós) submarine canyon (Northwestern Mediterranean). One of the major issues emerging from these efforts is the unexpected contribution of anthropogenic activities, namely deep bottom trawling, to the contemporary dynamics of sediment transport and accumulation in the canyon.

An intensive bottom trawl fishery has been active for at least the last 70 years along the flanks of the canyon from 350 to 800 m depth. A number of impacts associated to this human activity have been detected:

The heavy fishing gears are able, not only of eroding and reworking sediments but also of triggering sediment-laden flows on the steep canyon rims.

The magnitude and temporal evolution of the deep water column turbidity in an investigated lateral tributary is controlled by these man-made gravity flows and the effects are clearly seen to a minimum depth of 100 meters above the bottom. During working days and working hours of the trawling fleet, near-bottom suspended sediment concentrations reach up to 150 mg l-1 at a monitored site located 200 m deeper that the maximum working depth of the trawling fleet.

Gravity flows make their way to the main canyon axis influencing contemporary sediment dispersal and accumulation along the canyon. A doubling of the sediment accumulation rate has been observed in the lower canyon axis in coincidence with the industrialization of the fishing fleet in the 1970s. These results highlight that, on steep underwater environments such as submarine canyons, commercial trawling can become a relevant driver for sediment dynamics, not only on the fishing grounds but over larger and deeper areas.

Benthic foraminiferal patchiness in the Nazaré canyon, Portuguese margin

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Foraminifera are protists that often dominate modern deep-sea benthic communities. Hard-shelled species have an outstanding fossil record and are widely used to reconstruct past environments based on living species (Gooday, 2003; Jorissen et al., 2007). Although foraminifera are amongst the most important groups of deep-sea benthic organisms, one important faunal component, the soft-shelled species, which can represent 1/5th of the total foraminiferal abundance and diversity in the deep-sea (Gooday, 2002), are often overlooked. First we will characterize benthic foraminiferal communities inhabiting the Portuguese margin canyons (Nazaré and Setúbal) and adjacent slopes, including the soft-shelled species. Replication (still rare in foraminiferal studies) will ensure that patchiness can be assessed and results can be directly compared to macro- and meio-faunal studies. Published data from HERMES on metazoan meiofauna, macrofauna and megafauna are available, so we can compare protistan responses to environmental gradients with those of metazoans. It is important to find ecological commonalities between phylogenetically distant taxa in order to assess the extent to which fossilisable hard-shelled foraminifera can be used as proxies for general benthic community responses to environmental changes in ancient oceans. The benthic foraminiferal assemblages (including soft-shelled species) in replicate samples from the Nazaré Canyon were studied from samples collected in the middle (3200-3500m) and lower (4400 m) sections of the canyon during the HERMES cruise CD 179 (RRS Charles Darwin, 2006). The ñliveò (stained) and dead assemblages were analysed in terms of abundance, taxonomic composition, diversity and dominance, vertical distribution patterns within the sediment and live:dead ratios. In general, non-calcareous species were more abundant than calcareous species at both water depths. Gromiids (close relatives of the foraminifera) were the dominant taxon at the 3400 m station. These protists have soft walls and are unlikely to fossilize; thus, not including soft-shelled species will lead to an underestimation of benthic foraminiferal communities. The analysis of three replicate cores showed that ñliveò deep-sea foraminiferal communities are patchy. Less expected was the observation of patchiness in the dead (hard-shelled) assemblage, which is integrated over time and therefore should be more uniform.

Biodiversity in canyons ï macrofaunal assemblages in three canyon of the Iberian Margin

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The Western Iberian Margin is incised by several submarine canyons from which three were recently the subject of multidisciplinary research under the framework of the projects HERMES and HERMIONE. Nazaré, Cascais and Setúbal canyons are all three subjected to seasonal processes under the influence of the Iberian system of the North Atlantic upwelling

region but show contrasting geologic and internal hydrographical settings, and disturbance regimes. The macrofaunal taxonomic and functional composition, abundance, biodiversity and community structure was analysed from samples collected at the upper (900-1000m), middle (3200-3500m) and lower sections (4200-4500m) of the three canyons and at the adjacent open slopes (~1000m). Abundance in the upper canyons was significantly higher than in the adjacent slopes and in all canyons bathymetric trend was identical with peak abundances at intermediate depths. Depressed biodiversity coupled with high dominance occurred in the middle section of Nazaré and Setúbal but high biodiversity and low dominance were maintained along the depth gradient in Cascais. We documented a positive correlation between macrofauna abundance and total nitrogen concentration, and a negative correlation between biodiversity and total organic carbon concentration, confirming that organic loading is probably the major driver for structuring canyon benthic assemblages through a series of mechanisms that act on the availability of food and partitioning of resources by different species. Also relevant are multiple linked processes related to food inputs, disturbance and sediment heterogeneity.

Our results provide additional evidence for the view of canyons as important disruptions in abundance, biomass and diversity patterns both locally and regionally. They also show that even at a relatively narrow regional scale (100s km) these patterns are not consistent. The general lack of taxonomic resolution in canyon studies does not allow answering the controversy on whether or not canyons are hotspots of biodiversity. However our results suggest that canyons may show increased, decreased or identical biodiversity in relation to the adjacent margins depending on the complex interaction of several environmental drivers and the differential response of organisms and populations.

An ecosystem approach of the Capbreton Canyon

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The Bay of Biscay, NE Atlantic Ocean, shows interesting characteristics in terms of oceanography, geology/geomorphology and biology/resources. The Capbreton canyon, located in the south-eastern part of Bay of Biscay, differs from other canyons in many features: it beginning at less than 250 m from the shoreline. Moreover, with a length of about 300 km it is one of the largest European submarine valleys. It is an active canyon with a high amount of organic matter transported toward the bottom. This material has different origin pulses. Geologic cruise have been made and a high resolution Digital Model is available for a large part of deep area. The objective of this talk is to present a multidisciplinary approach to research on this area integrating physical and biological components.

Two regional projects are currently underway, that include a synthesis of the available knowledge on this canyon (Syntax project) and a study of fishing practices with boarding on commercial vessel (Loupe project).. Scientific survey including underwater observations should be considered to study biological aspects and habitat structure. From all these informationôs, the objective is to build a dynamic research to study the relations between fisheries, habitats and associated communities of this canyon. This research requires new

collaborations to compare the results of the Capbreton canyon with others based on their physical and geological similar characteristics.

Vulnerable Marine Ecosystems in French Continental Mediterranean Submarine Canyons : Spatial Distribution and Anthropogenic Impacts

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Adverse impacts to Vulnerable Marine Ecosystem (VME) in the deep sea has become an international concern since the United Nation has called on States and Regional Fisheries Management Organisations to prevent these impacts in 2007 (United Nation 2007). Food Agricultural Organisation has produced guidelines for management through an international consultative process in 2009 (FAO 2009). The biggest constraint in the process to protect VMEs is the uncertainties in the distribution and abundance of VME indicator species, and similar uncertainties in the link between fishing effort and significant adverse impacts. The General Fisheries commission for the Mediterranean (GFM) has edited a list of criteria for the identification of sensitive habitats of relevance for the management of priority species (GFCM 2009). The GFM has given a list of identified sensitive habitats which are (1) cold-water corals (*Lophelia pertusa* and *Madrepora oculata* communities) which form colonies supported by a common skeleton, providing structural habitat for other species (Peres & Picard 1964) (Zibrowius 1980) (Freiwald et al. 2009), (2) facies of soft mud with Funiculina quadrangularis (Peres & Picard 1964) (Bellan-Santini et al. 2002) (Michez et al. 2011) which is an essential habitat for some crustacean species (Parapenaeus longirostris and Nephrops norvegicus) and (3) facies of compact mud with Isidella elongata (Maurin 1962) (Peres & Picard 1964) (Bellan-Santini et al. 2002) (Michez et al. 2011) which is a relevant habitat for the fisheries targeted on red shrimps (Aristeus antennatus and Aristaeomorpha foliacea). Those habitats are sensitive because targeted by fisheries, but some other ecosystems are threatened by other anthropic pressions. For instance, the Cassidaigne canyon is the receiver of red mud discharged by the Gardanne Aluminium factory since 1967. Red mud extends into the abyssal plain up to over 50 km from the pipe (Dauvin 2010).

This pressure on natural marine resources and the demand for marine ecological services are considered to be too high and have led to the establishment of the European Marine Strategy Framework Directive (MSFD) (European Parliament 2008). This marine environmental policy established in 2008 aims at reducing impacts on marine waters considering that the marine environment is a precious heritage that must be protected, preserved and, where practicable, restored with the ultimate aim of maintaining biodiversity and providing diverse and dynamic oceans and seas which are clean, healthy and productive. The final objective of the MSFD is to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest.

The work was performed in the framework of the initial assessment of the marine bathyal waters in the French continental canyons. The study area covers the shelf break and the bathyal zone of the French continental margin in the northwest Mediterranean Sea. The French continental slope is cut by several canyons in the Mediterranean Sea (from 180 to

2000 m), 18 were taken into account in this study. Recent data were collected during Medseacan cruise organised by the ñAgence des aires marines protégéesò in 2009 and 2010. A total of 95 dives performed with the Achille Remote Operated Vehicle (ROV) from Comex (www.comex.com) were considered in this paper. To complete this dataset further deep in canyons, a total of 11 video films previously recorded from 430 to 2500 m by the Ifremer manned submersibles Cyana or Nautile, or by Ifremer Victor 6000 ROV were gathered when available, from Ifremer or from chief scientists (CYATOX, CYLICE, MEDECO, ESSNAUT, ESSROV). Multibeam data were collected during ESSROV2010 Ifremer cruise to complete scientific information regarding cold water corals settled in the Cassidaigne canyon.

We mapped with a GIS all the species, ecosystems and anthropogenic impacts recognized on video films. We assessed their spatial distribution in the heads of French continental canyons. Three objectives were pursued : (1) mapping Vulnerable Marine Ecosystems recognized by the General Fisheries commission for the Mediterranean (GFCM 2009), (2) assessing Cold-Water Coral habitat parameters in Cassidaigne canyon using multibeam bathymetric data, acoustic imagery and hydrodynamical data produced by a 3D-ocean model, (3) assessing the distribution of anthropogenic impacts on benthic ecosystems.

Interaction between downslope and alongslope processes in Biscay canyons; consequences for ecosystems & sedimentary architecture

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Over the last two decades, several research programmes have focussed on cold-water coral ecosystems along the European margin, with spectacular discoveries of giant cold-water coral mounds e.g. in the Porcupine Seabight. Their driving forces are seen as a complex interplay of geology, oceanography and nutrient supply. However, the occurrence of Lophelia pertusa and Madrepora oculata was already described in the Bay of Biscay by Joubin in 1922 and Le Danois in 1948. Here, the governing processes are distinctly more complex for the development of cold-water coral ecosystems, which can be ideal nurseries for deep-sea fish.

This paper presents an overview study of several sites along the Bay of Biscay, where the occurrence of alive cold-water corals (and the deep-water oyster Neopycnodonte zibrowii) between 500 and 1000 m can be related to a delicate balance between downslope and alongslope processes. The downslope processes are responsible for shaping the physical habitat, cutting out escarpments and banks. These currents are perfect organic matter suppliers from the productive shelf. On the other hand, alongslope processes are strongly influenced by the presence of Mediterranean Outflow Water (MOW), trapping the organic matter and keeping it into suspension. They may also be decisive for keeping the coral reefs free from

burial. The influence and importance of the MOW on the Biscay margins may need to be revised due to the discovery of several ï unexpected - sediment drifts along its pathway.

Most interestingly, fossil cold-water coral mini-mounds are observed at shallower water depths, just above the interface with the Mediterranean Outflow Water. They may be witness of brief but ideal environmental conditions during the last climatic termination, presenting analogues for cold-water coral mound growth. Moreover, some observations may hint at influences of hydrocarbon seepage.

Nazaré canyon bottom and suspended sediment dynamics, relation with grain-size and mineralogical signal

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There are two basic questions that have formed the basis for wider canyon studies over recent years: what are the mechanisms of the canyon today and what is its history and origin?
In this study we focus in the understanding of the present time transport capability of Nazaré canyon and in its potential of changing the characteristics of suspended matter and bottom sediments (grain size and compositional signal), associated with the main water masses (Eastern North Atlantic Central water and Mediterranean water).

Data referring to bottom and suspended matter collected in six surveys performed, between 2002 and 2010 by Instituto Hidrográfico, in the framework of EUROSTRATAFORM, HERMES and HERMIONE Projects, will be used to accomplish these objectives.

Canyon processes in sediment-undersupplied margins: Preliminary results from CUMECS cruise

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Current models of canyon formation fail to explain how canyons form in sediment-undersupplied margins or how canyons remain active after disconnecting from terrestrial/littoral sediment sources during high sea level stands. Sediment gravity flows are accepted as a dominant mechanism in canyon erosion, yet their source is not always well constrained. Recent studies stress the roles of hydrodynamic and slope failure processes in generating gravity flows and in widening canyons. These processes also regulate habitat diversity and abundance, but the extent of their influence in canyons is unknown and their monitoring is difficult.

CUMECS is an interdisciplinary project investigating the processes forming canyons in sediment-undersupplied margins and their influence on benthic habitats. An excellent natural laboratory for such a study is the Malta Escarpment, central Mediterranean Sea, which is incised by canyons that have remained largely isolated from inputs of fluvial/littoral sediments. Our hypothesis is that these canyons are primarily formed by hydrodynamic processes, widened by mass movements and that their location is controlled by tectonic structures. To test this hypothesis, we will integrate bathymetry and backscatter data, sub-bottom and high resolution seismic profiles, sediment cores and ROV imagery acquired from a Malta Escarpment submarine canyon. We will investigate these data using geomorphometry and state-of-the-art laboratory techniques to identify the nature, origin and role of the main processes/controls responsible for canyon initiation and development, to propose a model for canyon evolution in sediment-undersupplied margins, and to assess the impact of canyon processes on benthic habitats in such settings.

A research cruise, funded by EUROFLEETS, is planned for June-July 2012 to acquire geophysical and sedimentological data from the Malta Escarpment. During this workshop we will present data from this cruise and our preliminary interpretations.

Submarine canyon erosion processes and sedimentary activity at the head of the 2000km long Hikurangi margin sedimentary system, New Zealand.

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The Hikurangi Margin is an active subduction margin off New Zealandôs East Coast that hosts a large and varied population of submarine canyons. Canyons range in scale from slope gullies up to large, mature, shelf-incised systems, and feed sediment into a ~2000 km long deep-sea channel system within the sedimentary trough on the incoming Pacific Plate. We have recently collected a ~15,000 km2 Simrad EM302 bathymetric dataset that completes high resolution multibeam mapping of the ~30,000 km2 canyon-dominated seafloor. While a number of the canyons are known to be active only during low-stand sea-levels, some remain active during the present day. Canyons are forming and evolving through the action of hydrodynamic processes including down-slope sedimentary flows and by widespread deep-seated slope failure.

Sediment transfer into submarine canyons: observations and modelling of turbidity currents generation

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Numerical modelling of turbidity currents is becoming an important tool to the integration and the interpretation of sedimentary data in the deep-sea. The triggers of turbidity currents have been identified (hyperpycnal flows, earthquake triggering, slumping, gravity driven instabilities) but little is known to model the processes generating a turbidity current, i.e. to connect and transfer information and processes from the triggering mechanism (slope

instability, river plumes) to the generation, or initial condition, of turbidity currents. New ideas are developed on turbidity currents triggering and the capability to numerically model the generation of turbidity currents due (1) to river plume at hyperpycnal and hypopycnal conditions and (2) due to the transformation of submarine landslides and slumps.

Modelling propositions are developed on the basis of a fully no-linear description of key processes such as rheology, turbulence modulation in sediment-laden flows, settling features at high concentration integrating flocculation and hindering. Mathematical formulations are based on in-situ observations (river plume generated turbiditic events, slump transformation), flume data (turbulence modulation) and rheological experiments. The modelling approach manages information at different scales, from a geographically concentrated instability to a large scale propagation of turbidity currents, using a Smooth Particles Hydrodynamics (SPH) model (dynamic change in flow resolution) and a mesh based Eulerian morphodynamic model.

Main results show the threshold concentration in river flumes generating fluid mud layers near the sediment-water interface is related to limitation of settling flux at the sediment-water interface. This threshold concentration is lower (~5 g/l) than the concentration generating hyperpycnal flows (~40 g/l). This result explains the observation in active canyons (e.g. the Var) of turbiditic events related to hypopycnal conditions. A 3 equations based rheological model coupled to a turbulence closure model provides a large set of flow behaviours (from visco-elastic to fully turbulent), reproduces turbulence modulation as modelled in flume conditions and explains slump transformation as observed in-situ (from frozen slumps to turbulence driven flows).

From the present work we may conclude (1) turbidity currents may be generated by river flumes at hypopycnal conditions if sediment concentration induces settling fluxes overcoming the hindering settling flux at the deposition interface, where settling velocities are concentration dependent. (2) Turbidity currents may develop from slumps if the equilibrium Reynolds of the flows is associated to turbulent conditions. These are modelled and determined by the set of processes proposed and their mathematical expression.

Multiscale habitat mapping in Whittard Canyon, Celtic Margin

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Whittard Canyon is one of the western-most canyon systems along the Celtic Margin, Bay of Biscay. It is a dendritic system, comprising 4 main branches, each with its own morphological and sedimentological characteristics. In 2009, an extensive survey was carried out in the area, in order to map the canyon morphology, sedimentary environment and specific habitats, with the aim to assess the canyonôs role as potential ecosystem hotspot.

Because of the large extent of the system, a nested survey methodology was used, comprising ship-borne bathymetry, towed 30 kHz sidescan sonar (TOBI), ROV-based bathymetry and video work, plus a large number of seabed samples (various types of cores). The ROV bathymetry data, although only covering a small fraction of the total canyon area, has proven essential for the understanding of the terrain, the processes and the local habitats, and for

bridging the scale gap between the traditional ship-borne acoustic maps and the seabed samples and video. Despite spending 7 weeks in the area, only 2 canyon branches could be studied into any detail.

The first results illustrate the high morphological and habitat heterogeneity of the canyon. A difference between the eastern- most and western-most canyon branch can be observed, both in terms of terrain steepness (gullies, cliffs) and in terms of canyon activity. This is expected to have a profound effect on the benthic communities. Further research will now focus on the development of robust habitat mapping techniques which combine, in a quantitative way, the information provided at different scales, and which take into account the true 3D environment including the overhanging cliffs hosting extensive cold-water coral reefs observed in the eastern Whittard Canyon branch.

A Statistical Approach for Habitat Mapping in Portuguese Canyons

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Advances in technology have enabled numerous developments in deep-sea habitat mapping. As a result, a broad spectrum of data is increasingly being incorporated into seabed classification and many classification techniques have been proposed. Ideally, automated seabed classification for the deep sea is aiming for a statistically robust, objective and repeatable method, applicable at a variety of scales. This paper presents a study from the upper Cascais and Lisbon-Setubal Canyons offshore Portugal, and will address 3 of the main objectives in automated seabed classification: 1) objective parameter selection, 2) data clustering and 3) determination of the optimal number of classes. Prior to parameter selection, it is important to ensure all spatial data integrations are carried out correctly. To achieve this, TOBI sidescan data of high image quality but with poor locational accuracy were reprocessed using synthetic imagery produced from multibeam bathymetry. Subsequently, abiotic terrain variables (bathymetry & derivates, sidescan imagery, sediment properties) were subjected to a statistical approach using the Principal Component Analysis (PCA) to select optimum parameters for habitat classification. Unsupervised fuzzy clustering was used for data clustering. Lastly, the optimal number of clusters was obtained using within-‐groups sum of squares. The proposed method gave promising results in these submarine canyons with high terrain variability. TOBI reprocessing successfully improved the sidescan sonar imagery registration onto the multibeam bathymetry. The habitat maps are groundtruthed and evaluated using cross validation. The percentage of correctly classified pixel yields a worthy result. A critical evaluation using SLOT analysis on the overall method is carried out to identify its strength, limitations, opportunities and threats.

Vulnerable Marine Ecosystems in the Bay of Biscay

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Vulnerable Marine Ecosystems (VMEs) are defined as ñany deep-sea ecosystem (ecotopes: finest scale units used for mapping ecosystems) which has very high vulnerability to one or more kinds of fishing activityò. There are a number of communities that are listed as VMEs, including cold-water coral reefs, coral gardens, sponge dominated communities, seep and vent communities, and communities which are composed of epifauna that provide a structural habitat (e.g. xenophyophores and sea pens).

There are approx. 135 submarine canyons in the Bay of Biscay and within the French EEZ, along the French Margin, hosts an impressive and rugged topography. The environment within these canyons varies significantly and thus plays host to a diverse range of taxa, particularly corals. Early knowledge of these diverse habitats can be attributed to the work of Le Danois (1948) who described the regional fauna. Whilst this historical data has proven useful for understanding the fauna of the region, to better understand VME communities, we need better descriptions at a community level to aid conservation efforts.

Between 1981 and 2011, there have been 14 cruises in the Bay of Biscay, with over 100 dives using a range of imagery techniques. There is a diverse range of VME found in these canyons, with varying dominant taxa. The VME habitats range from impressive steep cliffs characterised by the reef-forming scleractinian *solenosmilia variabilis*, the gorgonian *Narella* and small colonies of *Lophelia pertusa*, to various coral garden communities, dominated by bamboo corals and antipatharians. The range and distribution of the VME habitats in the Bay of Biscay will be presented.

Posters

Neogene development and sedimentary processes of the Gollum channel system, Porcupine Seabight

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The Gollum Channel System is the only major downslope sediment supplying system located on the Irish Atlantic margin, first described in 1966. A decade ago, its structure and development was still poorly understood, compared with its counterparts on the Celtic and Armorican margins. A variety of data, collected from 1999 to 2006, has shed a new light on the upper reaches of this system. Additional to the UGent high-resolution seismic profiling, campaigns organised by associated partners acquired multibeam bathymetry, TOBI side-scan sonar data, a long piston core in one of the channels and new hydrographic data. Moreover, important chronostratigraphic information was obtained from the nearby IODP Exp. 307 sites.

These data allowed to clearly distinguish two different channel settings. The main Gollum channel system is characterised by several deeply incised canyons with numerous slide scars

on their flanks. Their pathways seem to be influenced by a structural control, creating a bayonet-shaped course. Upstream of this structural feature, the channel floor deposits are characterized by thick acoustically transparent units suggesting ponded turbidites or mass-wasting deposits. A long piston core, however, only yields a small number of fine-grained turbidites in a muddy hemipelagic host sediment. This implies that this system has known a relatively low activity during Quaternary times. Moreover, at the abyssal end of the slightly sinuous Gollum channel only a weakly developed deep-sea fan is found, confirming a low sediment supply.

In the northern part of the system, on the other hand, the Kings channels show an entirely different situation. Here the channels are broad and smooth with relatively gentle flanks. Along the longitudinal axis of the northernmost channel, an intra-channel levee is observed, suggesting a relatively higher bottom current activity compared with the southern Gollum channels. The most remarkable feature, however, is a large field of mass-wasting deposits and escarpments. This calls for a dramatic phase of slope instability within the Neogene. Until now, little evidence is found for the cause of this event. The evidence of pockmarks north of this area could invoke the mediation of fluid migration.

Anthropogenic impacts in submarine canyons of the Bay of Biscay

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Due to an increasing demand for resources, such as fossil fuels and food, and the decreasing reserves on land, human activities become more common in the deep sea environment. These activities are known to affect Vulnerable Marine Ecosystems (VMEs) that are found in the deep sea. While anthropogenic threats to the deep sea such as ocean acidification may prove detrimental, imminent threats are from the oil and gas industry, fisheries and marine litter.

VMEs are known to exist in submarine canyons. Specifically, the Bay of Biscay consists of 135 submarine canyons, of which 85 % lie within the French EEZ. These canyons host many Vulnerable Marine Ecosystem (VME) habitats, such as scleractinian coral reefs, coral gardens and sponge grounds. Such VME habitats are subjected to many human impacts, of which litter and fishing activities are the main pressures in the Bay of Biscay. In the last decade, vessel activity in the Bay of Biscay has increased; resulting in potential increases in litter discards from these vessels. France has a (deep-sea) fishing fleet as well, specially targeting Nephrops, monkfish and orange roughy. Video surveys acquired using Remotely Operated Vehicles (ROVs) and/or tethered cameras show evidence of fishing activity and marine litter. We present a description, including the distribution, of litter and fishing impacts where the main items found were plastics and lost (parts of) long-lines and fishing nets. Some remarkable objects that are potentially never recorded before, were observed as well. An indication of a damage rate as well as the possibility of corals and other species to re-colonise impact items is discussed.